Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

CONSUMER VALUATION OF HEALTH RISK: THE CASE OF HEPTACHLOR CONTAMINATION OF MILK IN HAWAII

by

William Foster and Richard E. Just

California Agricultural Experiment Station
Giannini Foundation of Agricultural Economics
June, 1984

CONSUMER VALUATION OF HEALTH RISK: THE CASE OF HEPTACHLOR CONTAMINATION OF MILK IN HAWAII

WILLIAM FOSTER and RICHARD E. JUST*

Cases of accidental chemical contamination of food sources are occurring with increasing frequency. Measurement of consumer welfare losses in such cases has presented difficult problems. Direct consumer questionnaires are unreliable because of strategic bias (consumers may overstate losses if they think it has possibilities for improving their situation). On the other hand, assessing losses by estimating the number of individuals that will be affected and multiplying by an average loss per person (estimating actual ex post losses) is a highly tentative approach because scientific and medical research estimates regarding the number of people actually affected (e.g., contracting cancer) are highly inaccurate. Also, the many means of estimating loss per person actually affected (implicit value of life from other comparisons, cost of treatment, and value of work time lost) produce conflicting results [Weinstein and Quinn (1983); Linnerooth (1979)]. Moreover, such ex post measures of consumer loss completely ignore the welfare loss associated with risk, i.e., the psychological costs of worrying about the possibility of contracting cancer, having deformed children, etc. As in the case of production under uncertainty, uncertainty about health effects has an important welfare effect whether or not the worst fears are realized (1) because decisions are consciously altered to avoid uncertainty and (2) because, in lieu of choosing an uncertain alternative, an individual may prefer a less uncertain situation even if he must give up something to obtain it [Just, Hueth, and Schmitz (1982); Pope, Chavas, and Just (1983).] These effects contribute to social welfare loss unless the uncertainty can be shifted to a risk-neutral party; and, in the case of health risks, such a shift may not be possible--some individuals may not be willing to accept any payment in lieu of their life or health.

Because revealed preference is the only way to measure how much consumers discount the value of a consumption good due to accompanying health risk (other than the dubious direct questioning approach), this paper focuses on developing the revealed preference approach to measurement of consumer losses. Estimation through observed behavioral data, however, also has problems because consumers usually have limited information about the true health risks imposed by various types of contamination. Excessive coverage in news media may lead to a consumer “scare” and, thus, cause unnecessary “avoidance costs” for consumers who consume less of the contaminated good than they would with perfect information. On the other hand, intentional withholding of information by polluting industries or government agencies may leave consumers unaware of a health risk in which case they would consume more than with perfect information.

Two recent studies have begun to develop a revealed preference methodology for estimating consumer losses due to specific chemically related health risks. Shulstad and Stoevener (1978) analyze a case where demand for hunting shifts with infomation regarding mercury contamination in Oregon pheasants. They calculate consumer surplus per hunter per season using demand-for-hunting equations estimated from survey data. Surplus losses due to the contamination are found by taking the product of the per hunter surplus and the reduction in number of hunters attributed to information regarding mercury in pheasants. Swartz and Strand (1981) examine a case where observed shellfish demand declines with information concerning the possibility of kepone contamination of oysters in the James River. They use an index of newspaper articles about the pollution of Virginia's James River to account for consumers' changing perceptions of product quality. Losses in welfare are calculated from the changing area under the market demand as it shifts with changes in the information index. A significant negative lagged effect of news reports on demand is found although, after four periods (eight weeks), the lagged index of information has a positive effect on demand.

The Shulstad-Stoevener paper provides an important extension of previous environmental literature by recognizing that individuals change their.behavior in response to information to avoid pollution and that avoidance reflects a social cost. The Swartz and Strand study makes a further contribution by recognizing that information may be imperfect. However, both of these studies suffer from some serious shortcomings. First, they use measures of information that may be very poor. Column inches of newspaper articles or numbers of articles, even weighted for specificity, may be poor measures because consumer valuations of the information are subjective. They may be influenced more by whether articles appear on front pages, or if stories are also carried on television, or if consumer action groups are also involved in publicizing or circulating petitions. A consumer action group that is working actively on public awareness relating to a food product in the parking lots of grocery stores can have an important effect for which direct data are usually not obtainable. More importantly, background information in various news stories can lead to much different subjective evaluations of the same data on contamination depending on how the evaluations are presented. All of these possibilities cannot be represented by a one-dimensional information variable.

A second aspect of such problems that lacks explicit consideration is consumer uncertainty. When news of contamination first breaks, it may cause considerable uncertainty and lead to “panic” avoidance because consumers do not know what to believe. Early news stories may be conflicting, whereas eventually more facts are understood and uncertainty declines. Furthermore, consumers usually face considerable uncertainty in translating contamination levels into probabilities of health loss or death given consumption. The accuracy of news stories in this regard depends on the extent of available medical research.

A third problem has to do with differentiating between correct and incorrect information in deciphering the associated welfare effects. In the Shulstad-Stoevener framework, an additional newspaper story reduces welfare regardless of whether the story is correct or incorrect and regardless of whether it suggests more or less contamination than previous stories. Thus, if news were simply not released, consumers would incur no “measured” welfare loss even though consumers may be consuming excessive mercury levels. A desirable framework should provide an appropriate way of calculating welfare losses to consumers in cases where news of contamination is withheld or undiscovered for some time. If a consumer attaches a given discount for uncertainty to a contaminated good, then he will presumably incur the associated loss (worrying, etc.) even if he only learns that the good was contaminated after consumption. The Swartz-Strand analysis alternatively suggests that, if information incorrectly suggests contamination and it is withheld until after most consumer decisions are made, then little welfare loss occurs. The Swartz-Strand approach demonstrates possibilities for measuring unnecessary avoidance costs assuming that information is inappropriately leading consumers to believe that contamination has taken place. A common case, however, is where some contamination takes place, and some information overstates the level of contamination. Thus, a framework, is needed to compare consumer welfare among situations of no contamination, contamination with correct information, and contamination with observed imperfections in information.

The purpose of this paper is to introduce an approach appropriate for handling these issues. The approach considers consumer decision making under uncertainty and uses an exact welfare calculation based on the expenditure function. In the following section, a model of consumer response to changes in a perceived probability distribution of contamination is developed. The succeeding section compares appropriate welfare measures with the classical Marshallian surplus. Then welfare measures reflecting consumer loss with different types of imperfections in information are developed--withheld information about contamination, excessive reporting of contamination, etc. Finally, an application of the framework to the 1982 heptachlor crisis of milk in Hawaii is presented. News of milk contamination by heptachlor--a pesticide used in pineapple production--was released in March, 1982, and caused monthly milk consumption on Oahu to decline by over 80 percent the following month.

I. A MODEL OF CONSUMER RESPONSE TO CONTAMINATION UNCERTAINTY

In order to examine the change in consumers' welfare associated with a change in perception of health risk, consider first the behavior of an individual consumer. Suppose a representative consumer is faced with the problem of allocating a given income between milk and all other goods. Suppose some quality characteristic associated with each unit of milk determines the

$$\max_{x} \overline{U}(x, m, \theta) \equiv E_\theta[\tilde{U}(x, m)]$$

where

$$\tilde{U}(x, m) = U(x, q, m - px)$$

for which the first-order condition is

$$\frac{\partial \overline{U}}{\partial x} = E_\theta\left[\frac{\partial U}{\partial x} - p\,\frac{\partial U}{\partial y}\right] \equiv 0 \tag{2}$$

assuming this condition is solved by some positive x and y = m - px.

To consider the comparative static behavior of the consumer in this framework, suppose quality is a random variable represented by

$$q = \mu + \sigma\varepsilon$$

where $\mu = E_\theta(q)$, σ represents a mean-preserving spread parameter (Sandmo), and the distribution of ε represents other parameters in θ. Then total differentiation of (2) can reveal the effects of changing information about quality as represented by the mean, μ, and the uncertainty or dispersion, σ. First,

$$\frac{dx}{d\mu} = -\frac{\partial^2 \overline{U}/\partial x\, \partial\mu}{\partial \overline{U}^2/\partial x^2}.$$

From concavity of the utility function, the second-order condition of the fixed quality problem,

$$\frac{\partial^2 \tilde{U}}{\partial x^2} < 0,$$

must hold for all quality levels. Thus, the second-order condition for (1)

$$\frac{\partial^2 \bar{U}}{\partial x^2} = E_\theta \left[\frac{\partial^2 \tilde{U}}{\partial x\, \partial q} \right] < 0,$$

must hold. Also, using assumptions above,

$$\frac{\partial^2 \bar{U}}{\partial x\, \partial \mu} = E_\theta \left[\frac{\partial^2 U}{\partial x\, \partial q} - p\, \frac{\partial^2 U}{\partial y\, \partial q} \right] = E_\theta \left[\frac{\partial^2 U}{\partial x\, \partial q} \right] > 0.$$

Thus, $dx/d\mu > 0$ so milk consumption responds positively to an increase in the mean of the subjective distribution of quality.

Similarly, the effect of a change in consumer quality uncertainty can be found by examining

$$\frac{dx}{d\sigma} = - \frac{\partial^2 \bar{U}/\partial x\, \partial \sigma}{\partial^2 \bar{U}/\partial x^2}.$$

Noting that

$$\frac{\partial^2 \bar{U}}{\partial x\, \partial \sigma} = \frac{\partial}{\partial \sigma} E_\theta \left[\frac{\partial \tilde{U}}{\partial x} \right],$$

the methods of Sandmo yield $\partial^2 \bar{U}/\partial x\, \partial \sigma < 0$ since

$$\frac{\partial^3 \tilde{U}}{\partial x\, \partial q^2} = \frac{\partial^3 U}{\partial x\, \partial q^2} - p\, \frac{\partial^3 U}{\partial y\, \partial q^2} = \frac{\partial^3 U}{\partial x\, \partial q^2} < 0,$$

i.e., for some function $f(q)$, $\partial E_\theta [f(q)]/\partial \sigma < 0$ if $\partial^2 f(q)/\partial q^2 < 0$. Thus, $dx/d\sigma < 0$ so an increase in milk quality uncertainty causes a decrease in milk consumption when the mean of the subjective milk quality distribution remains fixed.

The results of this section are important because they show that the effects of quality or contamination information on consumption cannot be reflected through a single information variable such as column inches of newspaper articles or numbers of articles. Information is a multidimensional variable. Since a change in the subjective mean of quality affects consumption differently than a change in the subjective variance, the data on information generally must be sufficiently rich to register their differential effects on these two important subjective parameters. In particular, when an initial “scare” leads to great consumer uncertainty which gradually declines with more information while the subjective mean quality declines sharply and then, say, remains low, data on information must be at least two-dimensional representing both the contamination level and uncertainty about the level.

II. EVALUATION OF WELFARE EFFECTS OF PERCEIVED QUALITY CHANGES

The most widely applied measure of change in a consumer’s welfare, brought about by a change in prices, quality, and the like, is his “willingness to pay.” (For a discussion of willingness-to-pay measures in applied welfare economics, see Just, Hueth, and Schmitz.) This paper focuses primarily on the compensating variation associated with an altered perception of the quality of milk brought about by a change in information available. When information which would have induced some response in the allocation of income is withheld from consumers, however, a better measure of willingness to pay is the compensating surplus. After considering these measures in the context of a change in quality or health risk, the paper turns to the problem of evaluating them using market data. For the compensating variation, the exact approach offered by Hausman (1981), Hanemann (1982), and Just, Hueth, and Schmitz

$$h(p, \bar{U}, \theta) = \frac{\partial e(p, \bar{U}, \theta)}{\partial p}. \tag{3}$$

These two properties are usually presented in a nonstochastic context but they hold in this case as well, given the assumptions above (Just, Hueth, and Schmitz).

The willingness to pay for a change in the probability distribution of quality of milk or health risk can be represented using either the indirect utility function or the expenditure function. Consider a change in information about quality or health risk which can be indicated by a change from θ_0 to θ_1. Holding other things constant, the compensating variation is defined as the amount required to be added to income (possibly negative) in order to keep the consumer as well off after the change as in the initial state if he is free to adjust his consumption in response to the (quality} change. In terms of the indirect expected utility function, this measure is defined by

$$V(p_0, m_0 + CV, \theta_1) = V(p_0, m_0, \theta_0) = U_0$$

where U_0 is the initial utility level or, in terms of the expenditure function,

$$CV = e(p_0, U_0, \theta_1) - e(p_0, U_0, \theta_0) = e(p_0, U_0, \theta_1) - m_0. \tag{4}$$

The change in area under the compensated demand curve at the initial utility level corresponds to this measure of consumer loss (gain). Thus, the compensating variation is a willingness to pay for the original quality distribution in lieu of the new one as revealed by actual behavior or demand choices. Similarly, the equivalent variation is defined as the amount required to be taken away from income (possibly negative) in order to keep the consumer as well off in the initial state as he would be if the change took place, i.e.,

$$V(p_0, m_0 - EV, \theta_0) = V(p_0, m_0, \theta_1) = U_1$$

or

$$EV = e(p_0, U_1, \theta_1) - e(p_0, U_1, \theta_0) = m_0 - e(p_0, U_1, \theta_0).$$

Defining $\hat{p}(\theta)$ as the lowest price where the compensated demand curve meets the price axis, i.e., $h(\hat{p}, \overline{U}_0, \theta) = 0$ (infinity if it does not), one finds from (2) and (3) that

$$CV = \int_{p_0}^{\hat{p}(\theta_0)} h_1(p, U_0, \theta_0)\, dp - \int_{p_0}^{\hat{p}(\theta_1)} h_1(p, U_0, \theta_1)\, dp,$$

assuming no externalities so that any change in quality of milk does not affect utility if milk consumption is zero (Just, Hueth, and Schmitz). The equivalent variation can be calculated similarly by conditioning on the subsequent rather than the initial utility level.

Figure 1 presents a graphical representation of the compensating variation when perception of quality or health risk changes. An indifference curve, $I(U_0, \theta_0)$, represents the initial iso-utility trade-off between milk, *x,* and all other goods, *y.* A change in information alters the preferences over milk and other goods. The new utility-maximizing trade-off attainable at the same income level is represented by $I(U_1, \theta_1)$. The initial bundle of goods is (x_0, y_0) at the tangency of $I(U_0, \theta_0)$ and the budget line, m - p*x.* The new bundle (x_1, y_1) is at the tangency of the budget line and $I(U_1, \theta_1)$; U_1 is the new level of utility. Assume $U_1 < U_0$ consistent with a deterioration in the subjective quality distribution; that is, suppose the new probability

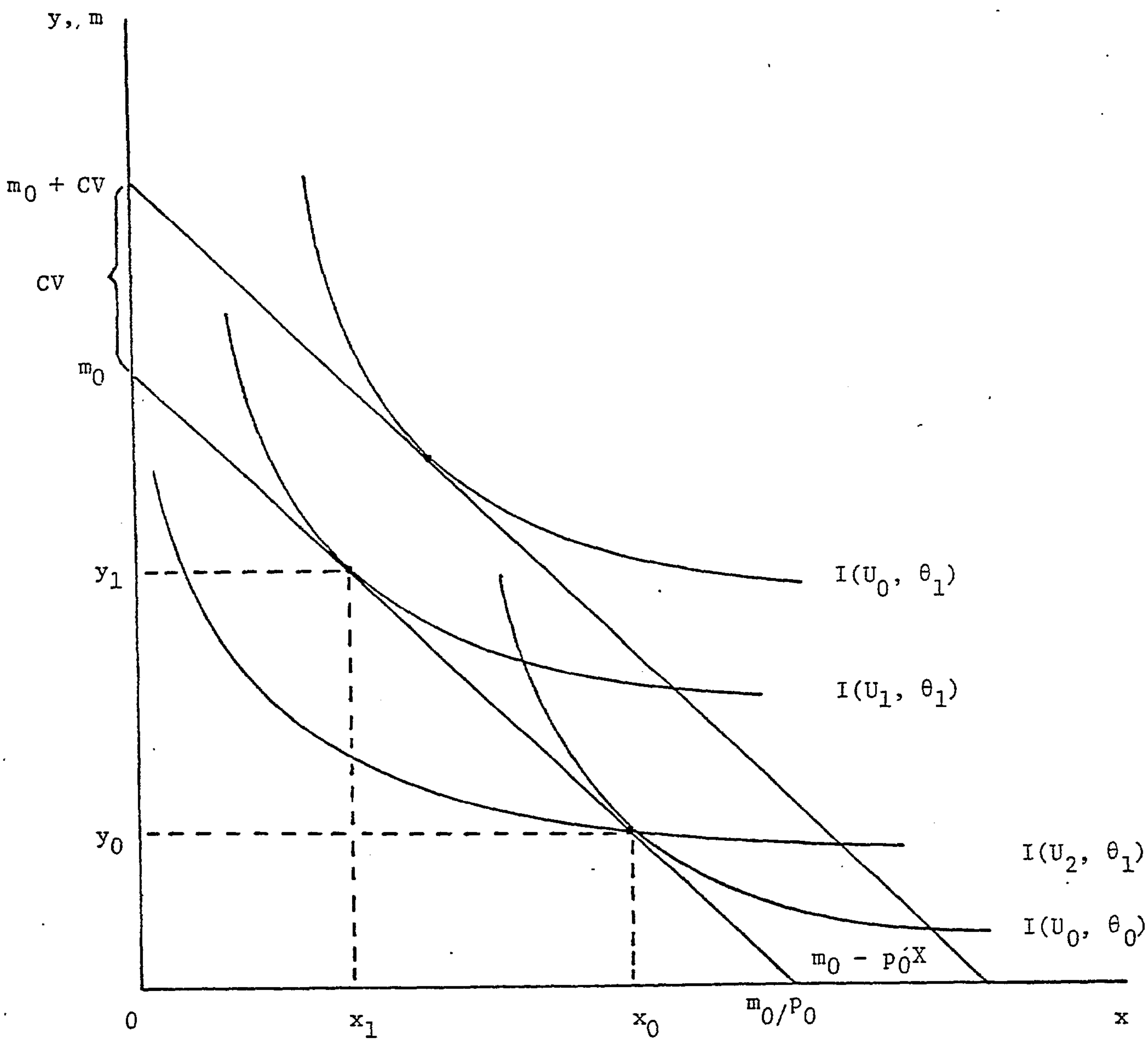

Figure 1. Consumer Loss with Quality Deterioration.

distribution of quality leads to a decline in expected utility and, thus, a substitution away from milk. In the case where quality is normally distributed, this would imply a decline in the mean, an increase in the variance, or both.

The compensating variation for a change from θ_0 to θ_1 is determined by finding the indifference curve associated with the initial level of utility and the new information, $I(U_0, \theta_1)$, and moving the budget line upward in parallel fashion until tangent with this indifference curve. The income, consistent with a budget giving U_0 for θ_1 less the initial income, is the compensating variation, CV. Note that this calculation assumes the consumer is able to alter his budget allocation to avoid some of the losses associated with a change from θ_0 to θ_1 since he adjusts to a tangency of the indifference curve with the new budget line. If the initial bundle were maintained, the consumer's utility would be U_2, represented by $I(U_2, \theta_1)$.

The compensating variation can be graphically displayed in another fashion as in Figure 2. Here the consumer welfare loss is represented by the difference in areas under the Hicksian demand curves with different subjective quality or health risk distributions, θ_0 and θ_1. The compensated demand for milk under the new perception of quality, θ_1, is lower for every price than the compensated demand under the initial θ_0, again representing a substitution away from milk. The compensating variation is given by the area under the initial demand, less the area under the new demand, or area abcd. Figure 2 also displays the Marshallian market demand curves with quality perpentions under θ_0 and θ_1. The Marshallian consumer surplus is the difference in the two areas under the Marshallian demands, area efcd.

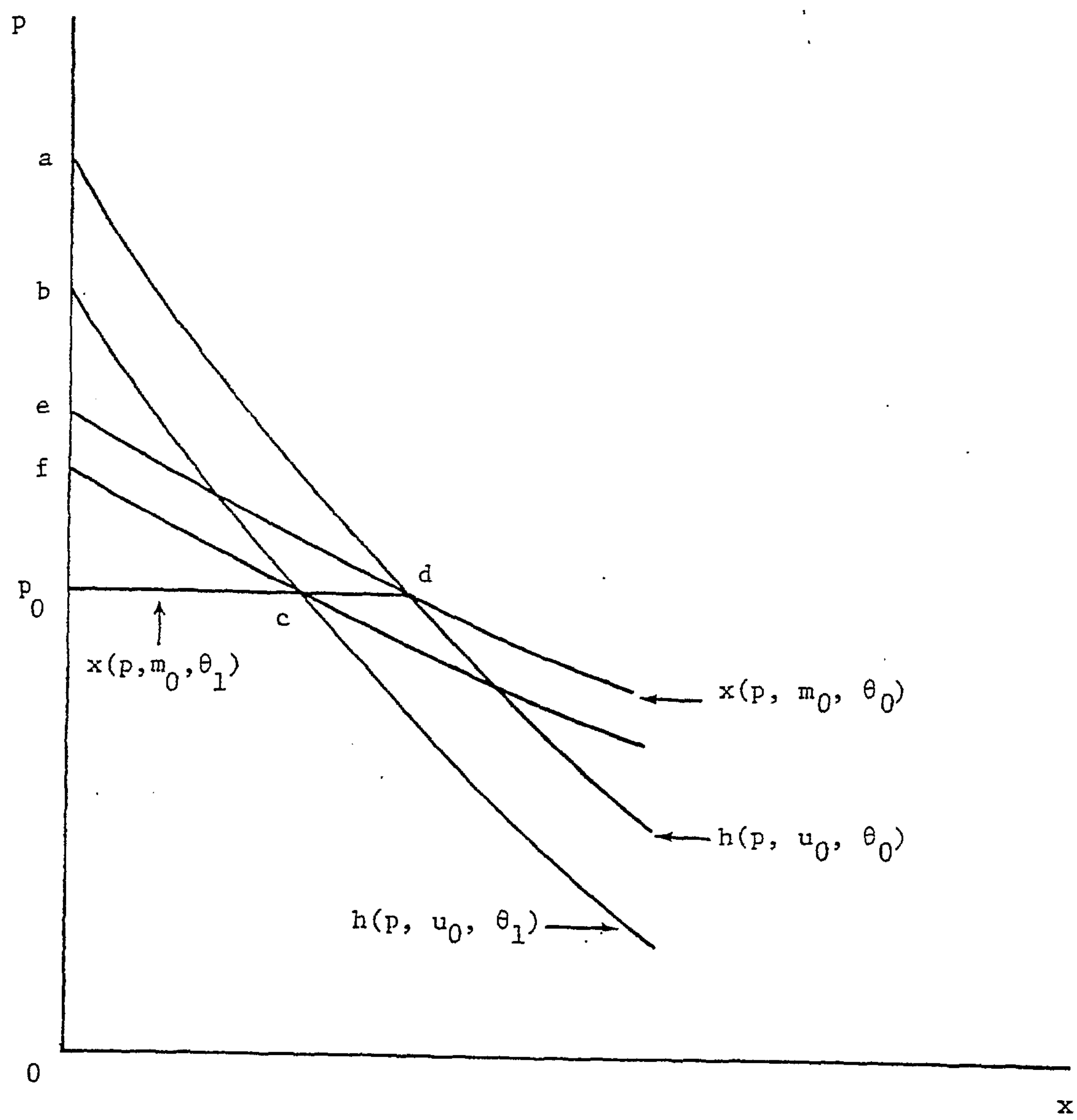

Figure 2. Measurement of Consumer Loss from Consumer Demand Behavior

III. THE COST OF IGNORANCE AND THE ROLE OF INFORMATION

The use of compensating or equivalent variations is appropriate for the evaluation of welfare changes due to changes in consumers' information regarding quality or health risk when consumers are free to adjust to the information. When consumers are not given certain information that could alter their behavior, however, they have no opportunity to avoid possible welfare losses or take advantage of additional gains by changing budgetary allocations. A different measure of welfare is needed to account for this cost of ignorance. The appropriate willingness-to-pay measure for evaluating a welfare change relative to the initial situation when consumption quantities are not free to adjust is the compensating surplus. Compensating surplus is the amount of money required to be added to income (possibly negative) in order to keep the consumer as well off after the change as in the initial state if he is not free to adjust consumption quantities other than of the numeraire. In the case of the model in this paper, the numeraire is good y.[3]

To consider measurement of compensating surplus using revealed preferences as observed in demand behavior, define the restricted expenditure function,

$$\tilde{e}(p, U_0, \theta, x_0) = \min_{x,y} px + y$$

subject to

$$x = x_0$$

and

$$E\,\{U(x_0, q, y)\} \geq U_0$$

The compensating surplus is defined by

$$CS = \tilde{e}(p_0, U_0, \theta_1, x_0) - \tilde{e}(p_0, U_0, \theta_0, x_0) = \tilde{e}(p_0, U_0, \theta_1, x_0) - m_0.$$

Graphically, this measure can be illustrated as in Figure 3 for the two-good case. As in Figure 1, a change in information from θ_0 to θ_1 alters the indifference curves for milk and other goods. Holding milk consumption at x_0, an income of m_0 + CS is necessary to achieve the initial level of utility, U_0, with the new perceptions of quality or health risk given the initial consumption level that would occur in ignorance. The additional cost of restricting milk consumption--the cost of ignorance--is simply CS - CV.[4]

Two final notes are in order concerning use of the compensating surplus for cases where information is withheld. First, the compensating surplus measure above assumes the consumer does not remain in ignorance. Following the old cliche, “ignorance is bliss,” if the consumer never learned of the contamination problem (and never experienced the adverse effects that are possible), then a welfare loss would not be realized. The assumption here is that correct information materializes soon relative to the time required to determine whether a particular consumer is one of those who experiences the worst possible effects (e.g., contracts cancer). Thus, essentially the same worry, concern, and uncertainty--in addition to real costs in the case of adverse consequences-- are incurred as if consumption were undertaken with correct information.

A second consideration is that the consumer may not make a change simply from a state of no information to either perfect information or continued ignorance. When news of contamination breaks, it may be over- or understated initially. For example, contaminating industries or government agencies may

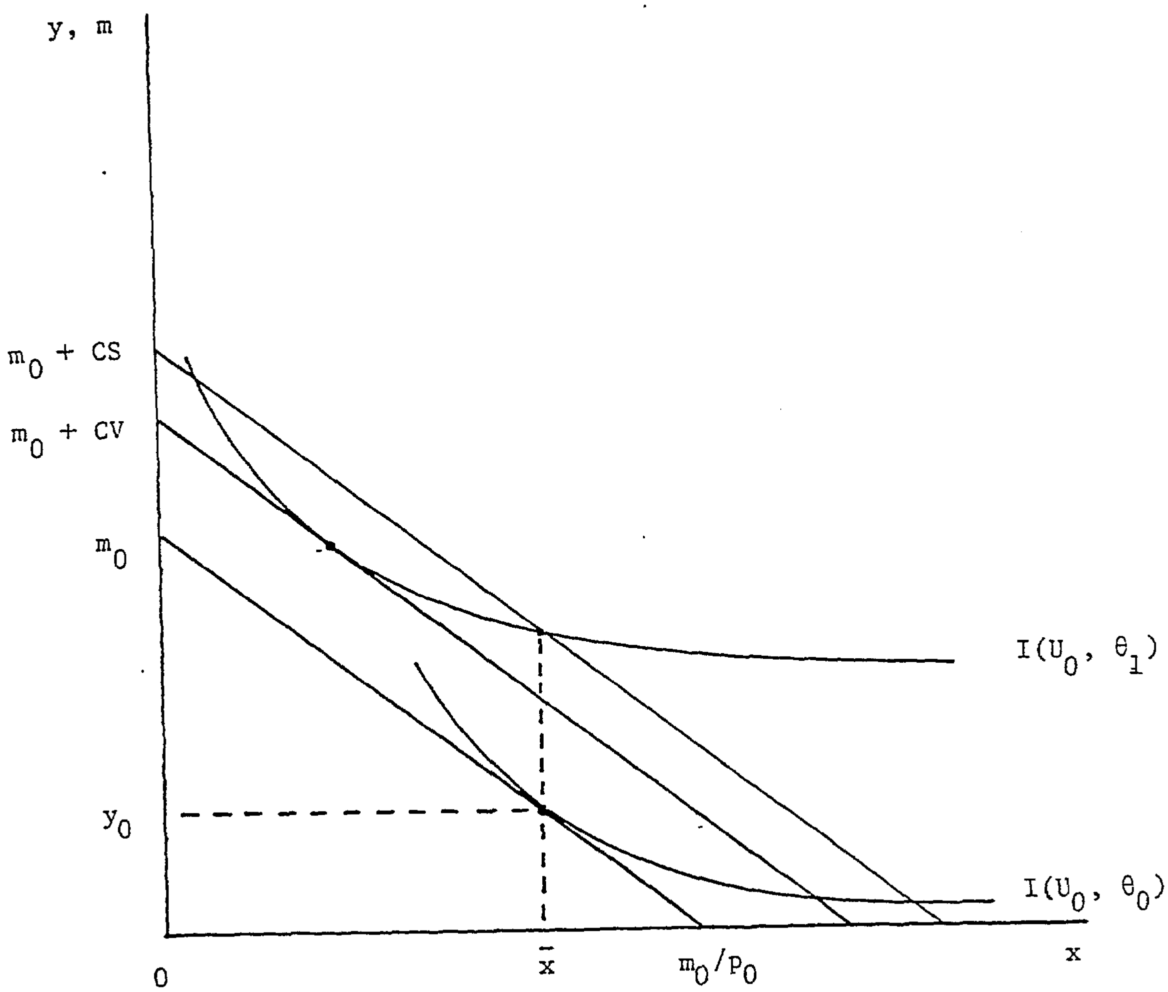

Figure 3. Consumer Loss with Quality Deterioration and Withheld Information.

(consciously or not) downplay the extent or significance, while news coverage may overstate the extent or significance. Suppose that initial information is correct and is described by θ_0, that the information changes to θ_1, and that correct information is given by θ_1^*. Then the consumer is influenced to adjust only to the information base, θ_1; thus, he consumes the associated quantity of milk rather than what he would consume with correct information. The associated welfare effect compared to the initial state is, thus,

$$\tilde{e}(p_0, U_0, \theta_1^*, x_1) - \tilde{e}(p_0, U_0, \theta_1, x_1) + e(p_0, U_0, \theta_1) - e(p_0, U_0, \theta_0)$$

$$= \tilde{e}(p_0, U_0, \theta_1^*, x_1) - e(p_0, U_0, \theta_0)$$

since $\tilde{e}(p_0, U_0, \theta_1, x_1) = e(p_0, U_0, \theta_1)$, i.e., x_1 is consumed voluntarily at (p_0, U_0, θ_1).

Alternatively, both the initial information and the information after the change may be incorrect. This may be the case if news of contamination has already appeared and is partially corrected. Suppose available initial information is described by θ_0, correct initial information by θ_0^*, available subsequent information by θ_1, and correct subsequent information by θ_1^*. Then the measure of welfare change must take account of errors in the initial allocation of income as well as the subsequent allocation of income. The appropriate measure of welfare compared to the initial situation is

$$\tilde{e}(p_0, U_0, \theta_1^* x_1) - \tilde{e}(p_0, U_0, \theta_0^*, x_0).$$

IV. MEASURING WELFARE CHANGES FROM MARKET DATA

Data regarding changes in perceived probabilities of quality levels are usually not available in cases where there have been unexpected changes have occurred in the consumers' environment. Available data are typically observations on consumer income and prices and quantities of goods exchanged. In addition, some variable may be available that reflects information by which consumers form their subjective probabilities. This section considers how changes in welfare can be evaluated using observed demand schedules, i.e., revealed preferences before and after changes in the environment or in information. Marshallian surpluses can be directly calculated from econometrically estimated demand curves. Alternatively, duality can be used *to* derive exact estimates of compensating or equivalent variation by use of market demands (aside from statistical error). Hausman; Hanemann; and Just, Hueth, and Schmitz show how the consumers' expenditure function or indirect utility function can be used to interpret observed data for this purpose by taking, advantage of the theory of consumer behavior.

First, following Hausman and Hanemann, note that the Marshallian demand curve for a good satisfies Roy's identity:

$$- \frac{\partial V(p, m, \theta)/\partial p}{\partial V(p, m, \theta)/\partial m} = x(p, m, \theta).$$

Maintaining utility at a constant level (remaining on an indifference curve), price and income must satisfy

$$\frac{\partial V[pd(t), m(t), \theta]}{\partial p} \cdot \frac{dp(t)}{\partial t} + \frac{\partial V[p(t), m(t), \theta]}{\partial m} \cdot \frac{dm(t)}{dt} = 0.$$

Therefore, income can be expressed as a function of the changing price

$$\frac{dm(p)}{dp} = x(p, m, \theta)$$

which is a differential equation and can be solved to obtain the expenditure function

$$m(p) = g(p, \theta, k) = e(p, \theta, U)$$

where k is a constant of integration that need not be known for calculating the differences in expenditure functions required for the welfare evaluation below.

Without loss of generality for welfare purposes, one can thus set k = $V(p, m, \theta)$; and the indirect expected utility function immediately follows from the estimated demand. Using the expenditure function derived from the observable demand, exact measures of compensating and equivalent variation can be derived as discussed earlier. This method of deriving the expenditure function offers only a local solution but suffices since only point estimates of the expenditure function (at θ_0 and θ_1) are needed.

One of the major advantages of beginning with or retrieving a representation of the indirect expected utility function underlying the observed market demand schedule, however, is the added ability to measure the costs associated with the absence of information relevant to consumer behavior. As discussed in the previous section, the compensating surplus can be evaluated using an expenditure function restricted such that the consumption of the good of interest is fixed. Such a restricted expenditure function is not directly derivable from a Marshallian demand. Nevertheless, the value of the compensating surplus can be indirectly determined once the unrestricted expenditure function is recovered.

The procedure for obtaining the compensating surplus can be illustrated for the two-good case as follows. Suppose prices, income, and information are at initial levels and a change in the environment occurs represented by a shift from θ_0 to θ_1. Then consider finding a price, p_1, such that the compensated demand at that price and with information parameters, θ_1, is equal to the initial level of consumption, x_0; that is, $h(p_1, U_0, \theta_1) = x_0$. The compensating surplus can then be calculated by

$$CS = [e(p_1, U_0, \theta_1) - p_1 x_0] - e(p_0, U_0, \theta_0) - p_0 x_0]$$

$$= e(p_1, U_0, \theta_1) - m_0 + (p_0 - p_1) x_0$$

since the only difference in the subsequent situation with p_1 versus p_0 is the difference in expenditure required to purchase x_0. The cost of ignorance is, thus, determined by

$$CI = CS - CV = e(p_1, U_0, \theta_1) + (p_0 - p_1) x_0 - e(p_0, U_0, \theta_1).$$

The price difference, $p_0 - p_1$, can be regarded as a measure of the substitutability between goods *x* and *y* at the initial levels of utility and consumption but with new information. As p_1 approaches p_0, the cost of ignorance approaches zero.

The empirical validity of this approach to calculating changes in welfare due to changes in information depends on how the parameters in θ enter the specification of the econometrically estimated demand. First, the paramters in θ should influence demand in a plausible way. For example, the (pp. 412-416) to determine exact measures of consumer welfare effects is employed. For the compensating surplus, this approach is extended somewhat to make further use of the consumer's response to prices.

Suppose the solution to the consumer's problem in (1) is represented by $x^* = x(p, m, \theta)$, a function of prices, income, and distribution parameters in θ. The expected utility evaluation at optimal consumption levels can be represented by the indirect expected utility function,

$$V(p, m, \theta) = E_\theta\{U(x^*, q, y^*)\},$$

where $y^* = y(p, m, \theta) = m - px^*$. The dual approach to this problem is to consider the expenditure function, minimizing the cost of attaining at least some given level of expected utility $\bar{U}$,

$$e(p, \bar{U}, \theta) = \min_{x,y} \ (px + y)$$

subject to

$$E_\theta\{U(x, q, y)\} \geq \bar{U}.$$

Both the indirect expected utility and expenditure functions have important properties for welfare measurement. First, Roy's identity reveals that the observed market demand curve is the partial derivative of $V(p, m, \theta)$ with respect to price divided by the marginal utility of income,

$$x(p, m, \theta) = - \frac{\partial V(p, m, \theta)/\partial p}{\partial V(p, m, \theta)/\partial m}.$$

Second, the partial derivative of the expenditure function, with respect to price, yields the Hicksian demand curve compensated for the level of utility, $\bar{U}$, parameters cannot simply be added as shifters. To illustrate, consider a linear demand curve estimated as

$$x(p, m, \theta) = \alpha p + \beta m + \gamma\theta.$$

This specification may lead to a good econometric "fit," but it implies the underlying expenditure function (see Hausman for details)

$$e(p, U, \theta) = e^{\beta p}\, U - \frac{1}{\beta}\left(\alpha p + \frac{\alpha}{\beta} + \gamma\theta\right),$$

which can be represented as

$$e(p, U, \theta) = e_1(p, U) + e_2(\theta).$$

The compensated demand curve for the good of interest, therefore, is not dependent upon the information change

$$\frac{\partial e(p, U, \theta)}{\partial p} = \frac{\partial e_1(p, U)}{\partial p} = \beta\, U\, e^{\beta p}.$$

Such a result suggests that the parameters of the quality or health risk distribution do not affect the consumers' welfare and, in particular, are theoretically inconsistent with the comparative static results of section I. According to theory, a reduction in the mean or an increase in the variance of the quality distribution leads to reduced consumption for all income and price levels.

Another consideration is the influence on welfare of information on quality when the good is no longer or barely consumed. For the case of the linear demand curve above, changes in θ result in the same changes in consumer welfare at all price levels. An appropriate specification should yield small changes in welfare due to quality-related parameters when the price of the good is very high and quantity consumed is very low.

V. AN APPLICATION TO THE HEPTACHLOR CONTAMINATION OF MILK IN HAWAII

Heptachlor is a highly toxic pesticide and carcinogen used by pineapple producers on the island of Oahu to kill ants upon which the mealybug depends. The mealybug is responsible for the damage of pineapple plants by secreting a substance that withers roots. Pineapple leaves and stems have been used as a fodder (called greenchop) for dairy cows because they are a cheap substitute for cattle feed imported from the mainland. Prior to 1982, dairy cows on Oahu were fed greenchop with residues of heptachlor, and the pesticide was passed on to humans through the consumption of local dairy products.

Essentially, the entire population of Oahu (approximately 800,000) was exposed to heptachlor-contaminated milk since no fluid milk was imported. The Department of Health of the state of Hawaii has estimated that dairy products contained 15 times the official acceptable level of the pesticide for adults.[5] Children may have been subjected to a greater level of exposure than adults because of their more frequent consumption of milk, particularly in schools.[6] Moreover, heptachlor was found in mother's milk and in infant's formula; thus, newborn infants, who are at greater risk from such toxins, were also exposed (Honolulu Advertiser 4-6-82, p. A1; Honolulu Star-Bulletin, 4-6-82, p. A1).

The public first became aware of the contamination problem on March 18, 1982, when the state's Health Department announced preparation to confront the rise in pesticide levels in milk. Throughout the next several months, the press followed the contamination crisis, offering consumers sometimes bewildering information on the safety of available milk supplies. The months of March and April, 1982, saw spectacular and troubling headlines addressing the issue, some of which are presented in Table 1. During these two months, daily milk consumption dropped from 32,259 gallons for February to 5,405 gallons for April (Table 2). By the beginning of May, however, the number of headlines in Honolulu's two major newspapers regarding the contamination of available supplies had declined from approximately 20 per week (immediately following the first disclosure) to approximately 4 per week.

After May, 1982, little or no information was found in newspapers suggesting continued contamination of milk on store shelves. Indeed, the reports were encouraging and indicated that available milk was safe and that quality restrictions were being tightened (Honolulu Star-Bulletin, 5-20-82, p. A1; Honolulu Advertiser, 9-24-82, p. A1). Consumers, however, remained wary throughout the balance of 1982, and consumption returned slowly to historically normal levels (Table 2). By the end of August, 1982, the Honolulu Advertiser (page A1) reported that 40 percent of the residents of Oahu were still uncertain about the quality of milk available. As further evidence, continuing public concern about the quality and health risk of Hawaiian milk led Safeway Stores, Inc., to apply for a license to import California milk to Hawaii based, in part, on a public survey that verified lower quality perceptions of milk produced on Oahu.[7]

One of the more disturbing aspects of this episode is the evident hesitance of state authorities to disclose information before the public became aware of the possibility of contamination. The state's Senate Committee on Health criticized the Department of Health for delaying the release of information to consumers (Honolulu Advertiser, 4-1-82, p. A1). Substantial political acrimony arose over this issue after the initial public

TABLE 1

A Sampling of Honolulu Newspaper Reports Concerning Milk Contamination[a]

Date	Sampling of newspaper reports
March 18, 1982	Department of Health officials prepare plan of action to deal with contamination of Island milk by pineapple pesticide (heptachlor). (Star., A3)[b]
March 19, 1982	Department of Health orders whole milk and some other milk products off Oahu grocery shelves because of pesticide. (Ad., A1; Star., A1)
March 20, 1982	Health officials try to assure residents that withdrawn milk was not really dangerous. (Ad., A1)
March 24, 1982	State Health Department orders all of Meadow-Gold’s 2 percent milk from store shelves after test shows unacceptably high heptachlor level. (Ad., A1; Star., A1)
March 26, 1982	State Department of Health clears two more dairy farms, bringing total of five without heptachlor; fourteen Oahu dairies continue to have excessive amounts of pesticide in milk. (Star., A1)
March 28, 1982	1,600 quarts of Foremost milk removed from Waikiki store shelves in third recall of pesticide-contaminated milk by State Department of Health. (Ad., A1; Star., A1)
April 6, 1982	Tests show mother’s milk contaminated with heptachlor. (Star., A1)
April 7, 1982	Milk recalls are over; Department of Health announces plan to test all milk products before they reach store shelves. (Ad., A4; Star., A1)
April 15, 1982	Experts dispute safety of mother’s milk in heptachlor controversy. (Ad., A4; Star., A1)

(Continued on next page.)

TABLE 1--continued.

Date	Sampling of newspaper reports
April 21, 1982	State Health Department recalls more Meadow-Gold dairy products; forbids dairy to use Oahu milk until it can insure that the milk it markets is "wholesome." (Ad.; A1)
May 20, 1982	Department of Health Director, Clark, says heptachlor levels in milk supply dropping steadily. (Star., A1)
September 27, 1982	Advertiser Hawaiian poll shows that 40 percent of residents are still uneasy about heptachlor in milk. (Ad., A)
December 24, 1982	Department of Health unexpectedly finds traces of heptachlor in Meadow Gold imitation milk. (Ad., A3)

[a]For a complete review of Honolulu newspaper articles on heptachlor, see Index to the Honolulu Advertiser and Honolulu Star-Bulletin, ed. James Hunt; published by the State of Hawaii.

[b]Ad. = Honolulu Advertiser, Star = Honolulu Star-Bulletin, and A1, A3, etc. = the section and page number.

TABLE 2

Fluid Consumption of Fresh Milk in Hawaii
January, 1981-August, 1983

Month	1981	1982	1983
	gallons per day		
January	34,556	31,821	28,668
February	34,947	32,259	28,905
March	32,127	16,402	31,681
April	35,520	5,405	31,299
May	34,858	15,221	31,571
June	30,590	20,611	26,972
July	31,304	22,215	27,267
August	30,943	22,873	28,345
September	34,434	24,843	a
October	33,527	23,131	
November	31,729	23,296	
December	31,002	23,852	

[a]Blanks indicate data not available.

Source: State of Hawaii, Department of Agriculture, Division of Milk Control (1977-1983).

reports of contamination (Honolulu Advertiser, 7-24-82, p. A3; Honolulu Star-Bulletin, 7-29-82, p. A3, and 8-5-82, p. A1].

To examine the consumer welfare effects of these developments, the Hawaii milk demand curve is estimated using monthly data on income, prices, and milk consumption in Hawaii. The estimated demand parameters are used in calculating compensating and equivalent variations for several months following the first disclosure of contamination. The Marshallian estimates of consumer surplus are also presented for comparison. Finally, the magnitude of additional monthly losses due to the withholding of information prior to March, 1982, are estimated. Although consumption in the months of March and April, 1982, was affected by Department of Health recalls, the statistics reported below assume that the recalls are consistent with voluntary choices consumers would have made with the same information. Nevertheless, this assumption only affects loss estimates based directly on March and April, 1982.

For the purpose of specifying demand, intuition implies that changing perceptions of health risk have a decreasing effect on milk demand and consumer welfare as the amount consumed decreases and that no additional losses in expected utility occur with further increases in the health risk if consumption is zero. Also, common sense indicates that the compensated demand curve is affected by perceptions of health risk in the same qualitative manner as the market demand although not necessarily to the same degree. A demand specification linear in the natural logarithms of the explanatory variables has these properties. Thus, let demand be represented by a function of the form

$$x_t = f_t(\theta_t)\, p_t^{\alpha}\, m_t^{\beta}$$

where $f_t(\theta)$ is a function of the parameters of the subjective health risk distribution and other determinants of demand, and the t subscript is added to index observations. In particular, θ represents the information consumers have regarding health risk.

The indirect expected utility associated with this demand is of the form

$$V(p_t, m_t, \theta_t) = \frac{m_t^{1-\beta}}{1 - \beta} - \frac{f_t(\theta_t)\, p_t^{1+\alpha}}{1 + \alpha}$$

from which the expenditure function is

$$e(p_t, U_t, \theta_t) = \left[(1 - \beta) \left(U_t + f_t(\theta_t) \frac{p_t^{1+\alpha}}{1 + \alpha} \right) \right]^{1/1-\beta} .$$

Note that, as p_t increases, the effect of the quality parameters in θ_t on expenditures decreases as long as $1 + \alpha < 0$. Also, as the relative price ratio, p_t, approaches infinity, the expenditure function approaches $[(1 - \beta) U]^{1/(1-\beta)}$ which is not dependent upon θ_t.

Finally, consider specification of $f_t(\theta_t)$ to account for other determinants of demand and the uncertainty surrounding health risk that followed the initial announcements of heptachlor contamination. Two major alternatives exist for specifying $f_t(\theta_t)$ to model changing information. The first involves specifying a dummy variable for each time period in which contamination information changes. The second involves specifying $f_t(\theta_t)$ as a function of the moments of the subjective health risk distribution and then specifying each moment as a function of actual information data. In either case, however, information must be recognized as a multidimensional variable if new but conflicting information of contamination can lead to increased uncertainty as well as a decline in average quality perceptions. With the dummy variable approach, the dimensionality of information is not limited, but errors in estimating other parameters of demand and, thus, attributing remaining variation to changes in information occur if information changes in too many observations of the sample. While the moment function approach does not suffer from these problems, the dimensionality of information is limited to, say, men and variance; and data may not be sufficient to identify all the parameters of the moment functions and of the moments in $f_t(\theta_t)$ unless a sufficient number of observations reflect changes in information. Also, problems may be encountered in obtaining data on all sources of information that may be affecting consumer perceptions.

Because of these data problems and because a relatively small proportion of the observations in the data set used here reflect changes in information, the dummy variable approach is used. Other determinants are included in a standard log linear component. Thus, $f_t(\theta_t)$ is of the form:

$$f_t(\theta_t) = As_t^{\gamma} \exp\left\{ \delta d_t + \sum_{\tau=0}^{T} a_\tau D_{t\tau} + b(1 + t)^{-c} D_t^* \right\};$$

where s_t is the price of a substitute; $d_t = 1$ if school is in session and $d_t = 0$ otherwise; $D_{t\tau} = 1$ if the observation represents month τ where information is changed and $D_t = 0$ otherwise; $D_t^* = 1$ if the observation represents any month following the first disclosure and $D_t^* = 0$ otherwise; and A, γ, δ, a_t, b, and c are unknown parameters. That is, t indexes months in 1982 with t = 0 in March, t = 1 in April, etc. Presumably, a large decrease in consumption occurred initially due to the changes in information; also, the uncertainty regarding health risk supposedly declined over time once news releases indicated safe heptachlor levels in milk. The latter term in brackets is included to represent this decline since $b(1 + t)^{-c} \to \infty$ as $t \to \infty$. Possibilities for representing this decline in uncertainty through the particular specification used here are shown in Figure 4 for several values of c. The long-run effect of information released in month t is the coefficient, a_t, which should be nonpositive for March and April, 1982, since news of contamination was released and the subjective health risk distribution was presumably worse than before . As is discussed above, newspaper reports indicated that milk supplies on store shelves were safe after April, 1982; and no evidence suggests that milk was actually unhealthy at that time. Therefore, the long-run effect of information is presumed to be the same as prior to contamination for the months following April (i.e., $a_t = 0$ for t = 2, 3, etc.).

This specification for $f_t(\theta_t)$ is convenient since it can be interpreted in terms of the consumers' perceptions of mean and variance. If any changes in the quality distribution are completely characterized by mean and variance, then the term a_t can be interpreted as a proxy for the long-run mean effect of the information released in month t; and the term $b(1 + t)^{-c}$ captures the variance effect since uncertainty declines over time. The data used to estimate the parameters of milk demand are per capita monthly consumption of fluid milk; monthly price indices for milk and meat products in the Honolulu area, as reported by the Bureau of Labor Statistics (meat is the substitute); and per capita income for Hawaii.[8] The estimated coefficients of demand, using monthly data from January, 1978, to July, 1983, are as follows (t statistics are in parentheses):

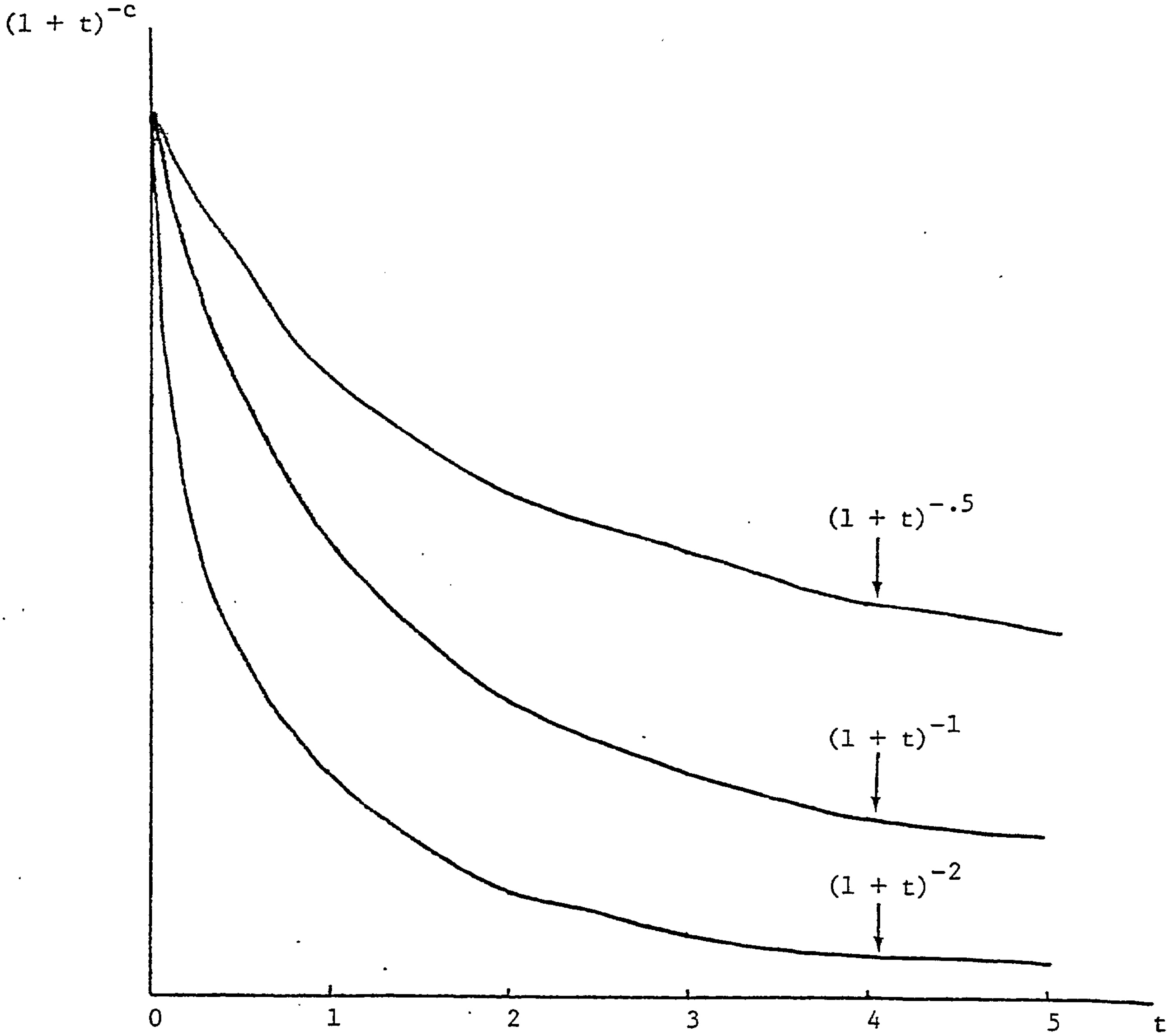

Figure 4. Graph of $(1 + t)^{-c}$ for c = .5, 1, 2

$$\ln x_t = -0.56 - \underset{(-4.20)}{1.30} \cdot \ln (p_t/m_t) + \underset{(2.89)}{0.89} \cdot \ln (s_t/m_t) + \underset{(1.41)}{0.05} \cdot d_t$$

$$- \underset{(-7.97)}{2.30} \cdot \text{March} - \underset{(-0.94)}{0.46} \cdot \text{April} - \underset{(-1.34)}{4.02} \cdot \underset{(2.68)}{(1 + t)^{-1.57}} \cdot D_t^*$$

where the names of the specific months are used to represent the D_t dummy variables.

The results of the regression are intuitively plausible. The price elasticity of milk is negative. A milk price elasticity greater than unity in absolute value seems large compared to mainland studies but is explained by the tropical climate. The price elasticity of meat (substitutes) is positive and less than unity implying that the income elasticity of milk is less than unity ($\beta = -\alpha - \gamma = 1.30 - .89 = .41$). The long-run coefficients on the contamination months are negative, as are the coefficients on the uncertainty function, which is consistent with theoretical considerations.

From the expenditure function, the compensating variation for a change from θ_0 to θ_1 can be represented as

$$CV = e(p_0, U_0, \theta_1) - e(p_0, U_0, \theta_0)$$

$$= \left\{ (1 - \beta) \left[- \frac{f(\theta_0)\, p_0^{1+\alpha}}{1 + \alpha} + \frac{m_0^{1-\beta}}{1 - \beta} + \frac{f(\theta_1)\, p_0^{1+\alpha}}{1 + \alpha} \right] \right\}^{1/(1 - \beta)} - m_0$$

$$= \left\{ \frac{1 - \beta}{1 + \alpha} \frac{p_0(x_1 - x_0)}{m_0^{\beta}} + m_0^{1-\beta} \right\}^{1/(1-\beta)} - m_0$$

where

$$U_0 = -\frac{f(\theta_0)\ p_0^{1+\alpha}}{1+\alpha} + \frac{m_0^{1-\beta}}{1-\beta}$$

$$x_0 = f(\theta_0)\ p_0^{\alpha}\ m_0^{\beta}$$

$$x_1 = f(\theta_1)\ p_0^{\alpha}\ m_0^{\beta}.$$

Similarly, the equivalent variation can be represented as

$$EV = e(p_0, U_1, \theta_1) - e(p_0, U_1, \theta_0)$$

$$= m_0 - \left\{\frac{1-\beta}{1+\alpha}\frac{p_0(x_0 - x_1)}{m_0^{\beta}} + m_0^{1-\beta}\right\}^{1/(1-\beta)}$$

where

$$U_1 = -\frac{f(\theta_1)\ p_0^{1+\alpha}}{1+\alpha} + \frac{m_0^{1-\beta}}{1-\beta}.$$

The change in the Marshallian consumer surplus is given by

$$\Delta S = \int_{p_0}^{\infty} f(\theta_0)\ p^{\alpha}\ m_0^{\beta}\ dp - \int_{p_0}^{\infty} f(\theta_1)\ p^{\alpha}\ m_0^{\beta}\ dp$$

$$= [f(\theta_0) - f(\theta_1)]\ m_0^{\beta}\ \frac{p^{1+\alpha}}{1+\alpha}$$

$$= \frac{p(x_1 - x_0)}{1+\alpha}$$

assuming $1 + \alpha < 0$.

These three measures of consumer welfare loss are computed for March, 1982, through September, 1982, based on the estimated equation above. The estimates compare the actual contamination that occurred assuming correct consumer subjective assessments of health risk with the hypothetical possibility of no contamination (and no news of contamination) for each month. The estimates are striking in several ways. First, the magnitude of loss is very high--higher than the value of milk normally consumed in some months. This is, indeed, possible and plausible, however, since Hicksian demands are more inelastic than Marshallian demands, since the Marshallian demand is close to inelastic, and since consumption fell by such a large amount. Thus, the change in area under the Hicksian demand and above price can be larger than the area below price and left of the initial quantity. A second striking result, which is to be expected, is the very sharp increase in consumer losses initially and then the rather rapid and, finally, more prolonged decline in losses (Table 3). However, the monthly loss declined below the value of fluid milk normally consumed under conditions prior to the heptachlor crisis only by August, 1982.

While the above results give some important information regarding the magnitude of consumer losses after information of contamination became available, one of the greatest and most controllable losses may have occurred prior to public awareness. For example, some reports indicate that public officials may have been aware of the contamination problem as early as April, 1981, 11 months before the public was informed. Individuals who consumed milk from April, 1981, to March, 1982, still face the same risks from heptachlor consumption as if they had been forced to consume normal amounts of milk with knowledge of heptachlor contamination. Thus, the associated welfare loss from

TABLE 3

Per Capita Consumer Welfare Losses
March, 1982-September, 1982

Month	Variation: Compensating	Variation: Equivalent	Marshallian consumer surplus change
		dollars per month	
March	6.33	6.31	6.32
April	8.84	8.80	8.82
May	5.43	5.42	5.32
June	3.36	3.35	3.36
July	2.73	2.73	2.73
August	2.45	2.45	2.45
September	2.57	2.57	2.57

Source: Computed.

contamination can be measured by the compensating surplus, and the welfare loss associated with withholding the information can be measured by the cost of ignorance measure defined in section IV.

To illustrate these concepts, suppose that appropriate information in, say, February, 1982 (the month before the news release), should have led to the same subjective distribution of quality that existed in April, 1982 (the month after the release). To do this, let θ_0 represent actual information in February (information dummy variables in the estimated equation are all zero) and let θ_1 represent the hypothetically true information in February as reflected by the actual information in April (information dummy variables at April levels). Following the methodology of section IV, a hypothetical price p_1 was first found such that

$$\frac{\partial e(p_1, U_0, \theta_1)}{\partial p_1} \equiv f(\theta_1)\, p_1^{\alpha} \left\{ (1 - \beta)\left[U_0 + \frac{f(\theta_1)\, p_1^{1+\alpha}}{1 + \alpha}\right]\right\}^{\beta/(1-\beta)} = x_0$$

(by numerical methods). Then the compensating surplus (which compares to releasing correct information with no chance to adjust to information of contamination) is

$$CS = e(p_1, U_0, \theta_1) - m_0 + (p_0 - p_1)\, x_0$$

$$= \left\{ (1 - \beta)\left[U_0 + \frac{f(\theta_1)\, p_1^{1+\alpha}}{1 + \alpha}\right]\right\}^{1/(1-\beta)} - m_0 + (p_0 - p_1)\, x_0.$$

In this case, p_0 = \$3.22 per gallon, p_1 = 80 cents per gallon, x_0 = .909 gallons per person, m_0 = \$971, and $e(p_1, U_0, \theta_1)$ = \$978.45. Thus, the compensating surplus is \$9.85.

As one would expect, this implies a larger welfare loss per month prior to the release of information than after consumers are free to adjust and avoid some of the contaminated milk. The welfare loss (compensating variation) in April, for example, when consumers could make more informed decisions, was \$8.84 by comparison. Thus, the cost of ignorance was apparently a little over \$1.00 per person per month for each month public officials withheld information

VI. CONCLUSIONS

This paper has developed an approach for measurement of consumer welfare losses associated with health risks from chemical contamination. Estimated actual cost criteria (value of life lost, productivity foregone, or cost of treatment) ignore the effects of inherent risk and uncertainty that enter into consumer evaluations of well-being whether or not actual costs are incurred. This problem can be overcome through direct estimation of willingness-to-pay criteria from revealed preferences (actual demand data).

Another important point of this paper is that information about contamination is not a one-dimensional variable. Early information may be spotty and inconsistent and thus lead to increased uncertainty in addition to a perception of a decline in quality. A multidimensional variable cannot be represented by a single index of news coverage. In problems where sufficient data exists over a noncontaminated period just preceding a comparatively short contaminated period (as in this study), a dummy variable specification has more flexibility in capturing all the effects of a changing subjective distribution of quality. However, separation of the effects into, say, a mean effect and a variance effect becomes more arbitrary. By comparison, if contamination effects are to be calculated over many time periods, then estimates of other parameters may tend to stray because the dummy variables make the contamination period ineffective in estimating price and income elasticities. On the other hand, when many observations exist over a contaminated period, observed data can be sufficient to consider estimating, say, both subjective mean and variance functions for quality based on specific information and discrepancy of information data on news stories. Such a specification can facilitate use of some of the theoretical concepts of this paper not demonstrated in the empirical work that relate to changing levels of contamination with changing but imperfect information on contamination. This study chose the dummy variable approach for simplicity in illustrating the basic methodology and because the major changes in subjective health risk perceptions apparently took place over a very short time following a period perceived to be free of contamination.

A final point that represents the most important departure of this study from previous work is that contamination, prior to public awareness, causes welfare losses for consumers that can be measured by revealed preferences. Compensating surplus can be used to measure willingness to pay when a consumer is not informed and, thus, does not have the opportunity to adjust consumption accordingly. While this measure cannot be calculated directly from estimated market demand, it can be calculated indirectly by solving a related differential equation to find the expenditure function and finding a hypothetical equivalent price. Results show that consumer losses from contamination when information is withheld can be greater than after information is released. In particular, estimates for the Hawaiian heptachlor crisis show that consumer losses prior to consumer awareness in March, 1982, may have exceeded the losses incurred since and that over 10 percent of the losses incurred before consumer awareness may be due to withholding of information by public officials.

FOOTNOTES

*William Foster is Research Assistant and Richard E. Just is Professor of Agricultural and Resource Economics, both at the University of California Berkeley. This research was supported by a grant from the Environmental Protection Agency.

[1]For the derivation here, milk is assumed to be a good rather than a bad for all levels of quality for simplicity. This is not inconsistent with observed behavior of zero consumption if milk price is positive. However, the framework can be easily expanded to consider $\partial U/\partial x < 0$ for low q if a restriction $x \geq 0$ is added.

[2]The latter assumption can be relaxed to a substantial degree but only at a significant cost of complication of presentation.

[3]This is a somewhat unusual definition of compensating surplus made necessary by the fact that welfare measurements here concern quality change rather than the usual price change. However, as long as good *y* serves as the numeraire, a change in *y* is equivalent to a change in income; thus, the welfare effect can be measured equivalently by either a change in *y* or a change in income.

[4]Note that the usual definition of equivalent surplus, the remaining candidate of Hicks's four consumer welfare measures, is not an appropriate measure here since it constrains consumption levels to the subsequent adjusted level--a level that would not be reached either before or after a quality change in the case of withheld information. However, a similar alternative appropriate measurement would be provided by

$$ES = e(p_0, U_1, \theta_1, x_0) - \tilde{e}(p_0, U_1, \theta_0, x_0).$$

[5]For a further discussion of the heptachlor “crisis,” see State of Hawaii, Senate Special Committee (1983).

[6]After the contamination became known, however, public schools offered imitation milk in place of whole milk; see, for instance, the Honolulu Advertiser (March 19, 1982, p. A7) and the Honolulu Star-Bulletin (March 19, 1982, p. A3).

[7]For a review of this issue, see State of Hawaii, Department of Agriculture (1977-1983).

[8]While meat is not usually considered as a substitute for milk, several reasons lie behind its use here. First, meat is a major competing source of protein. Second, milk does not have a good close substitute. For example, cereal and milk may be replaced by eggs and sausage, with sausage being the major cost item. Third, milk consumption in the tropical Hawaiian climate is believed to behave differently than on the mainland where comparable studies have been done. Finally, empirical results supported the meat price specification and failed to support inclusion of other more common variables.

REFERENCES

Hanemann, W. Michael. "Some Further Results on Exact Consumer's Surplus." University of California, Department of Agricultural and Resource Economics, Working Paper No. 190. Berkeley, 1982.

Hausman, J. A. "Exact Consumer's Surplus and Deadweight Loss." American Economic Review 71 (September 1981):662-676.

Just, R. E.; D. L. Hueth; and A. Schmitz. Applied Welfare Economics and Public Policy. Englewood Cliffs: Prentice-Hall, Inc., 1982.

Linnerooth, J. "The Value of Human Life: A Review of the Models." Economic Inquiry 17 (January 1979):52-74.

Pope, R.; J. Chavas; and R. E. Just. "Economic Welfare Evaluation for Producers Under Uncertainty." American Journal of Agricultural Economics 65 (February 1983):98-107.

Sandmo, A. "Competitive Firm Under Price Uncertainty." American Economic Review 61 (March 1971):65 -73.

Shulstad, Robert N. and Herbert H. Stoevener. "The Effects of Mercury Contamination in Pheasants on the Value of Pheasant Hunting in Oregon." Land Economics 54 (February 1978):39-49.

State of Hawaii, Department of Agriculture, Division of Milk Control. Statistical Reports, January 1977-July 1983.

State of Hawaii, Department of Agriculture. "Notice of Hearing Officer's Recommended Decision in the Matter of Safeway Stores, Inc." 1983.

State of Hawaii, Senate Special Committee. "Report of the Senate Special Committee Investigating Heptachlor Contamination of Milk." 1983.

Swartz, D. G., and I. E. Strand. "Avoidance Costs Associated with Imperfect Information: The Case of Kepone." Land Economics 57 (May 1981):139-150.

Weinstein, M. O., and R. J. Quinn. "Psychological Considerations in Valuing Health Risk Reductions." Natural Resources Journal 23 (July 1983): 659-673.